



## ***Verification***

The undersigned, I sincerely declare and verify the fact that I truly translated Korean Patent Applications No. 10-1999-0056162.

Signature:

A handwritten signature in black ink, appearing to be "Chan-Joo YOUN", written over the date.

Date:

January 18, 2006

Name:

Chan-Joo YOUN

# **KOREAN INDUSTRIAL**

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**Applicant(s)** : LG. Philips LCD Co., Ltd.

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[BIBLIOGRAPHICAL DOCUMENTS]

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[TITLE OF INVENTION IN KOREAN] 광시야각을 갖는 액정표시장치

[TITLE OF INVENTION IN ENGLISH] Liquid crystal display device with wide viewing  
angle

[APPLICANT]

[NAME IN KOREAN] 엘지. 필립스 엘시디 주식회사

[NAME IN ENGLISH] LG. Philips LCD Co., Ltd.

[APPLICANT CODE] 1-1998-101865-5

[ATTORNEY]

[NAME] Jung, Won-Ki

[ATTORNEY CODE] 9-1998-000534-2

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[INVENTOR]

[NAME IN KOREAN] 손현호

[NAME IN ENGLISH] SON, HYEON HO

[IDENTIFICATION NO.] 720112-1785418

[ZIP CODE] 431-058

[ADDRESS] 605-212 Saetbyul Apt., Daran-dong, Dongan-gu, Annyang-si,  
Gyeonggi-do, Republic of Korea

[NATIONALITY] KR

[PURPORT] We submit application as above under the article 42 of the Patent Law.

Attorney

Jung, Won-Ki (seal)

[FEES]

|                              |          |        |     |
|------------------------------|----------|--------|-----|
| [BASIC APPLICATION FEE]      | 20 pages | 29,000 | won |
| [ADDITIONAL APPLICATION FEE] | 3 pages  | 3,000  | won |
| [ PRIORITY FEE ]             | 0 things | 0      | won |
| [ EXAMINATION REQUEST FEE ]  | 0 clamis | 0      | Won |
| [ TOTAL ]                    |          | 32,000 | Won |

[ENCLOSED] 1. Abstract, Specifications (with Drawings)\_1 set

## [DOCUMENT OF ABSTRACT]

### [ABSTRACT]

The present invention relates to a liquid crystal display device, and more particularly to a liquid crystal display device having a wide viewing angle. Since a plurality of domains where liquid crystal molecules have different alignment directions are obtained by forming concave or convex unevenness at both sides of a pixel electrode and a slit at a center of the pixel electrode on an array substrate for a liquid crystal display device, a liquid crystal display device having a wide viewing angle is achieved.

### [REPRESENTATIVE FIGURE]

FIG. 6

## [SPECIFICATIONS]

### [NAME OF INVENTION]

Liquid crystal display device with wide viewing angle

### [BRIEF EXPLANATION OF FIGURES]

FIG. 1 is an exploded perspective view of a transmissive color liquid crystal display device according to the related art.

FIG. 2 is a magnified plane view of a portion of an array substrate for a liquid crystal display device having a wide viewing angle according to the related art.

FIG. 3 is a cross-sectional view taken along a line “III-III” of FIG. 2.

FIG. 4 is a magnified plane view of a portion of an array substrate for a liquid crystal display device having a wide viewing angle according to another related art.

FIG. 5 is a cross-sectional view taken along a line “V-V” of FIG. 4.

FIG. 6 is a cross-sectional view of a portion of an array substrate according to a first embodiment of the present invention.

FIG. 7 is a cross-sectional view of a portion of an array substrate according to a second embodiment of the present invention.

FIG. 8 is a cross-sectional view of a portion of an array substrate according to a third embodiment of the present invention.

FIG. 9 is a cross-sectional view of a portion of an array substrate according to a fourth embodiment of the present invention.

FIG. 10 is a cross-sectional view of a portion of an array substrate according to a fifth embodiment of the present invention.

\* Explanation of major parts in the figures \*

101 : pixel electrode

103 : slit

105 : common electrode

113 : transparent electrode

## [DETAILED DESCRIPTION OF INVENTION]

## [OBJECT OF INVENTION]

## [TECHNICAL FIELD OF THE INVENTION AND PRIOR ART OF THE FIELD]

The present invention relates to a fabricating method of a liquid crystal display device, and more particularly to a liquid crystal display device having a wide viewing angle.

A display device that treats and displays a large amount of information has been subject of recent researches since the coming of information age.

Cathode ray tube (CRT) devices have been commonly used for display devices, and recently flat panel display (FPD) devices having excellent operational characteristics, such as portability, light weight and low power consumption are being developed. Accordingly, thin film transistor liquid crystal display (TFT-LCD) devices have been developed because of their high color reproducibility and thin profile. In addition, a size of a liquid crystal display device has been gradually enlarged.

As a display area of a liquid crystal display device becomes larger, a viewing angle quality becomes more important among various quality factors of the liquid crystal display device.

To improve a viewing angle, additional means such as retardation films or diffusion layers were adapted to a liquid crystal panel of the liquid crystal display device.

Further, a liquid crystal display device where a viewing angle is improved by varying an operation mode and having different orientations in liquid crystal molecules has been researched.

In detail, a plurality of horizontal electric fields having different field directions are generated by making distribution of common electrodes and pixel electrodes non-uniform. First liquid crystal molecules are aligned along a first horizontal electric field, and second liquid crystal molecules are aligned along a second horizontal electric field having different field direction from the first horizontal electric field. Accordingly, the first liquid crystal molecules constituting a first domain have a different alignment direction from the second liquid crystal molecules constituting a second domain.

Since a plurality of domains having different alignment directions are constituted, a liquid crystal display device having an improved viewing angle is obtained.

Hereinafter, a schematic structure of a liquid crystal display device will be illustrated.

FIG. 1 is an exploded perspective view of a related art color liquid crystal display device.

As shown in FIG. 1, a liquid crystal display (LCD) device 11 includes upper and lower substrates 5 and 22 with a liquid crystal layer 14 interposed therebetween. The upper and lower substrates 5 and 22 are referred to as a color filter substrate and an array substrate, respectively.

In the upper substrate 5, a black matrix 6 and a color filter layer 7 are formed on a surface opposing the lower substrate 22. Further, a common electrode 18 is formed on and covers the color filter layer 7 and the black matrix 6.

In the lower substrate 22, a switching element “T” such as a thin film transistor is formed on a surface opposing the upper substrate 5, and a plurality of crossing gate and data



lines 13 and 15 are positioned such that each switching element “T” is located near each cross point of the gate and data lines 13 and 15. Further, a pixel electrode 17 is formed in a pixel region “P” defined by the gate and data lines 13 and 15.

The pixel electrode 17 is formed a transparent conductive metal such as indium tin oxide (ITO).

FIG. 2 is a magnified plane view of a portion of an array substrate for a liquid crystal display device having a wide viewing angle according to the related art.

To obtain a wide viewing angle, an array substrate for a liquid crystal display device is fabricated by modifying shapes of a common electrode and a pixel electrode.

A pixel 17 is formed in a pixel region “P.” A thin film transistor (not shown) as a switching element is formed at crossing of a gate line 13 and a data line 28 and connected to the pixel electrode 17.

In the pixel region “P” in the lower substrate 20, an additional side electrode 19 is formed surrounding the pixel electrode 17.

An upper substrate is spaced apart from a lower substrate 11, and a common electrode 18 having a slit 21 along a first direction is formed on the upper substrate.

The slit 21 of the common electrode 18 on the upper substrate corresponds to a boundary of domains and an area where a common voltage is not applied to generate a horizontal electric field due to the pixel electrode 17, the common electrode 18 and the side electrode 19 and apply the horizontal electric field to liquid crystal molecules.

FIG. 3 is a cross-sectional view taken along a line “III-III” of FIG. 2.

As shown in FIG. 3, a horizontal electric field is generated in the liquid crystal cell due to the pixel electrode 17, the common electrode 18 on the upper substrate 5 (of FIG. 1) over the pixel electrode 17 and the side electrode 19 surrounding the pixel electrode 17 and having

a voltage different from that of the pixel electrode 17. The horizontal electric field is divided into two electric fields that have different field directions and constitute first and second domains “A” and “B” with the slit 21 of the common electrode 17 as a center. The two electric fields 34 are directed from the pixel electrode 17 to the side electrode 19 adjacent to the pixel electrode 17.

Since the liquid crystal molecules are aligned in different directions in the first and second domains, a wide viewing angle is obtained.

FIG. 4 is a schematic plane view showing a pixel region of a liquid crystal display device according to another related art.

As shown in FIG. 4, a structure of FIG. 4 is the same as that of FIG. 3 except that a rib 19 of an insulating polymeric material is formed on the upper substrate instead of a slit.

FIG. 5 is a cross-sectional view taken along a line “V-V” of FIG. 4.

As shown in FIG. 5, a pixel region “P” is divided into two domains “C” and “D” with the rib 20 as a center. The two electric fields 24 are directed from the pixel electrode 27 to the side electrode 29 adjacent to the pixel electrode 27.

Accordingly, liquid crystal molecules in the two electric fields are aligned along different directions to constitute a multi-domain where alignment directions are different from each other in the liquid crystal cell.

A multi-domain structure where liquid crystal molecules are aligned along different directions can be obtained through the above two methods.

As shown in FIGs. 3 and 5, however, in the above-mentioned conventional liquid crystal display device having a multi-domain structure, the side electrode is formed in a pixel region with the pixel electrode. Accordingly, the area of the pixel electrode decreases to reduce the aperture ratio. The actual aperture ratio of the above-mentioned liquid crystal

display device is about 45 % while that of the typical twisted nematic liquid crystal display (TN-LCD) device having a mono-domain structure is about 60 %. The decrease in aperture ratio results in decrease in brightness by about 30 %.

Further, to form the slit or the rib on the common electrode, an additional photolithographic process is required to make the fabricating processes much more complicated.

#### [TECHNICAL SUBJECT OF INVENTION]

To solve the above problems, the object of the present invention is to provide a liquid crystal display device having a wide viewing angle and a high brightness.

#### [CONSTRUCTION AND OPERATION OF INVENTION]

To achieve these and other objects and in accordance with the purpose of the present invention, as embodied and broadly described, a liquid crystal display device includes: first and second substrates; a common electrode on the first substrate; a pixel electrode including a slit on the second substrate, the pixel electrode having an uneven portion at edges thereof, the uneven portion protruding toward the common electrode; and a liquid crystal layer interposed between the first and second substrates.

The liquid crystal display device further includes a first electrode having the same voltage as the common electrode. The first electrode is formed under the slit of the pixel electrode. The first electrode may be a data line.

The liquid crystal display device further includes a rib of an insulating material over the uneven portion of the pixel electrode.

In another aspect, a liquid crystal display device includes: first and second substrates;

a common electrode on the first substrate; a pixel electrode including a slit on the second substrate, the pixel electrode having an uneven portion at edges thereof, the uneven portion outwardly protruding from the common electrode; and a liquid crystal layer interposed between the first and second substrates.

The liquid crystal display device further includes a first electrode having the same voltage as the common electrode and formed under the slit of the pixel electrode.

The liquid crystal display device further includes a rib of an insulating material on the common electrode.

Hereinafter, reference will now be made in detail to the preferred embodiment of the present invention, example of which is illustrated in the accompanying drawings.

-- First embodiment --

A first embodiment of the present invention provides a multi-domain structure including a slit on a pixel electrode.

FIG. 6 is a schematic cross-sectional view showing a pixel region of a liquid crystal display device according to a first embodiment of the present invention. As shown, a pixel electrode 101 includes a slit 110 at a central portion thereof. Edges "E" of the pixel electrode 101 are bent to form convex portions instead of side electrodes in the related art liquid crystal display device.

Two horizontal electric fields 104a and 104b are induced with the slit as a center due to the common electrode 113 over the slit and the pixel electrode by the side of the slit. The two horizontal electric fields 104a and 104b have different field directions, thereby a two-domain structure is formed in one pixel region.

When the convex portions are not formed at the edges “E” of the pixel electrodes 101, liquid crystal molecules over the edges of the pixel electrode is influenced by a data line elongated along the edges of the pixel electrode rather than by the common electrode 113.

Accordingly, a single domain has various field directions of electric fields and a required domain of liquid crystal molecules is not obtained.

When the convex portions is formed at the edges “E” of the pixel electrode 101, field directions of the electric fields near the edges “E” coincide with the field directions of the two horizontal electric fields with the slit 105 as a center, respectively. Therefore, a multi-domain structure where an alignment direction is uniform in one pixel region is obtained.

The convex portions of the pixel electrode may have various heights. For example, the height of the convex portions is substantially greater than the one-tenth of a cell gap between the upper and lower substrates on the basis of experiment.

As mentioned above, since an additional photolithographic process for a slit in the common electrode on the upper substrate is not required and opaque side electrodes are not formed, aperture ratio is improved.

#### -- Second embodiment --

In a second embodiment of the present invention, a center electrode is formed under a slit in a pixel electrode. FIG. 7 is a schematic cross-sectional view showing a pixel region of a liquid crystal display device according to a second embodiment of the present invention.

As shown, a center electrode 105 is further formed under a slit 103. The center electrode 105 may be formed in the same layer as a gate line 13 (of FIG. 1) that supplies a scan signal to a pixel region or may be formed in the same layer as a data line that crosses a

gate line and supplies a data signal to a pixel electrode 101. Further, the center electrode 105 may be simultaneously formed with the data line.

A voltage that is the same as a voltage of a common electrode 113 is applied to the center electrode 105 under the slit 107.

Accordingly, two domains “F” and “G” where two horizontal electric fields 106a and 106b having different field directions from the pixel electrode to the slit are respectively induced are obtained with the slit 107 in the pixel electrode 101 of one pixel region as a center. As a result, a liquid crystal display device having a multi-domain structure is formed.

-- Third embodiment --

In the third embodiment, a data line 107 substitutes for a center electrode 105 under a slit 103 in a pixel electrode 101 of the second embodiment.

FIG. 8 is a schematic cross-sectional view showing a pixel region of a liquid crystal display device according to a third embodiment of the present invention. As shown, a data line 107 is used as a center electrode under a slit 103. As a result, the convex portions are formed at a center between two adjacent pixel electrodes. Accordingly, a multi-domain structure having two different alignment directions 106a and 106b in one pixel region is obtained.

Since a multi-domain structure is obtained without forming additional side electrodes 19 (of FIG. 1) and an additional center electrode under the slit in the pixel electrode, aperture ratio is further improved.

For example, the aperture ratio increases by about 55%, and the brightness increases by more than about 20%.

-- Fourth embodiment --

FIG. 9 I is a cross-sectional view showing a pixel region of a liquid crystal display device according to a fourth embodiment of the present invention.

As shown, a rib 109 is further formed on a common electrode corresponding to a convex portion at edges “E” of a pixel electrode.

The rib 109 is disposed to oppose the convex portions “E” of the pixel electrode, and may be used as a spacer for keeping a cell gap between the upper and lower substrates.

Since the rib excludes influence by lines adjacent to the edges “E” of the pixel electrode, a more stable multi-domain structure having two domains “F” and “G” is obtained.

-- Fifth embodiment --

In the fifth preferred embodiment, more domains are defined in a pixel region.

FIG. 10 is a schematic cross-sectional view showing a pixel region of a liquid crystal display device according to a fifth embodiment of the present invention. As shown, a pixel electrode includes a slit 103 to divide a pixel region into two sub regions, and two ribs 108a and 108b of an insulating material are formed on a common electrode to correspond to centers of the two sub regions, respectively. In addition, concave portions are formed at both sides of a pixel electrode 101 differently in the first to third embodiments.

Herein, due to the concave portions at edges of the pixel electrode, liquid crystal molecules in outward domains “H” and “K” of the two ribs 108a and 108b are aligned along horizontal electric fields between the pixel electrode 101 and data lines (not shown) adjacent to the pixel electrode 101.

The concave portions may have a height substantially greater than one-tenth of a cell gap between the upper and lower substrates (not shown).

Accordingly, one pixel region may be divided into two sub regions by the slit, and the two sub regions may be divided into four domains “H,” “I,” “J” and “K” to form a multi-domain structure.

As a result, a stable multi-domain structure having a larger number of domains is obtained in the fifth embodiment.

The first to the fifth preferred embodiments of the present invention provide the multi-domain liquid crystal display devices having the wide viewing angle.

In each preferred embodiment, though not shown in figures, first and second orientation films are preferably formed on the common and pixel electrodes, respectively. The orientation film is alternately rubbed via a fabric, or light.

Further, the liquid crystal interposed and aligned in the multi-domains is preferably vertical alignment (VA) liquid crystal. A low twisted nematic (LTN) liquid crystal (LC) having a twist angle of 10 to 80 degrees is also preferably employed for the liquid crystal display device according to the preferred embodiments. When employing the LTN-LC, the width of the slit should be smaller than that of the center electrode (the data line) to prevent light leakage through the slit.

#### [EFFECT OF INVENTION]

In a liquid crystal display device according to the present invention, since an additional slit for a wide viewing angle is not formed on a pixel electrode on an upper substrate, an additional photolithographic process is not required and a fabrication process is simplified. Further, since an additional opaque side electrode is not formed in a pixel region, a liquid crystal display device having high aperture ratio is obtained.



[RANGE OF CLAIMS]

[CLAIM 1]

A liquid crystal display device, comprising:

first and second substrates;

a common electrode on the first substrate;

a pixel electrode including a slit on the second substrate, the pixel electrode having an uneven portion at edges thereof, the uneven portion protruding toward the common electrode; and

a liquid crystal layer interposed between the first and second substrates.

[CLAIM 2]

The device according to claim 1, further comprising a first electrode having the same voltage as the common electrode.

[CLAIM 3]

The device according to claim 1, wherein the first electrode is formed under the slit of the pixel electrode.

[CLAIM 4]

The device according to claim 3, wherein the first electrode is a data line.

[CLAIM 5]

The device according to claim 1, further comprising a rib of an insulating material over the uneven portion of the pixel electrode.

[CLAIM 6]

A liquid crystal display device, comprising:

first and second substrates;

a common electrode on the first substrate;

a pixel electrode including a slit on the second substrate, the pixel electrode having an uneven portion at edges thereof, the uneven portion outwardly protruding from the common electrode; and

a liquid crystal layer interposed between the first and second substrates.

[CLAIM 7]

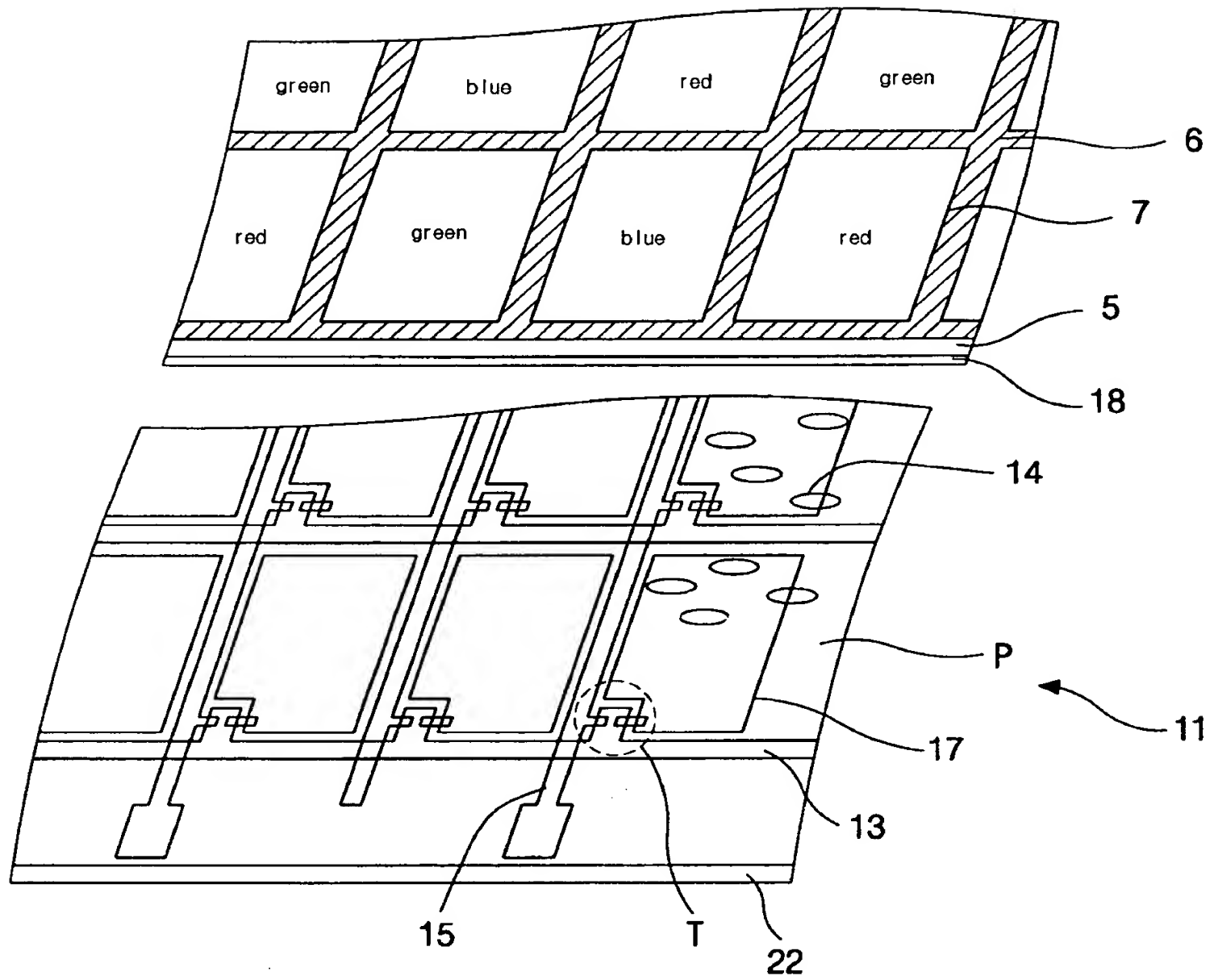
The device according to claim 6, further comprising a first electrode having the same voltage as the common electrode and formed under the slit of the pixel electrode.

[CLAIM 8]

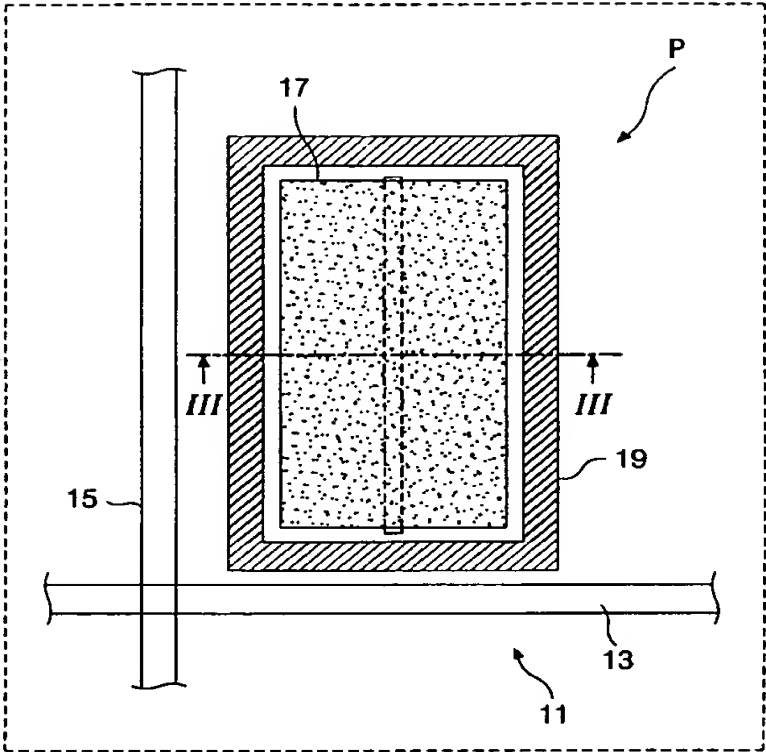
The device according to claim 6, further comprising a rib of an insulating material on the common electrode.

[DRAWINGS]

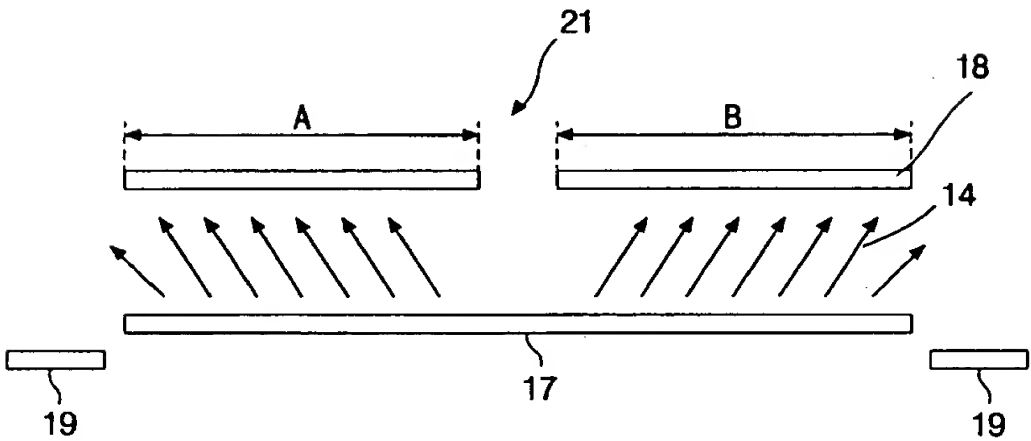
[ FIG. 1 ]



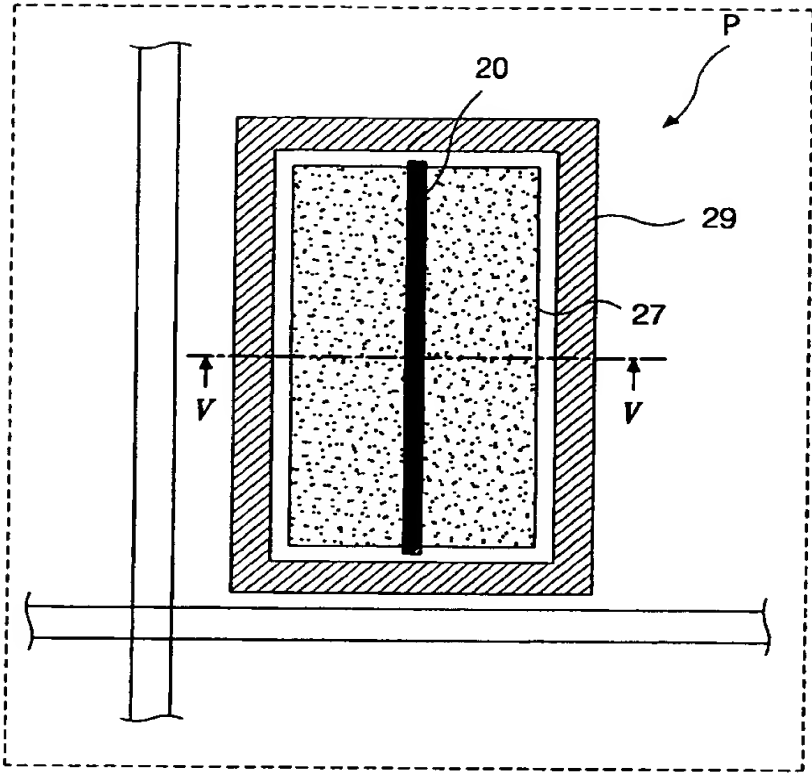
[ FIG. 2 ]



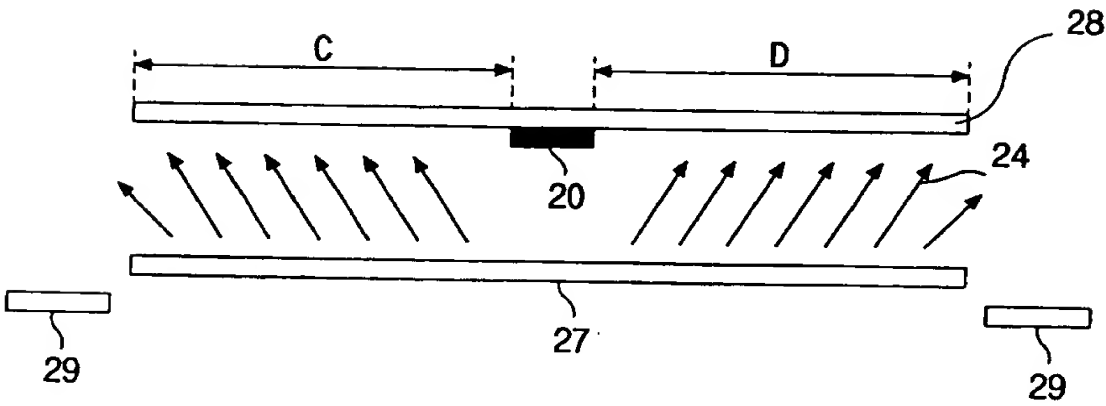
[ FIG. 3 ]



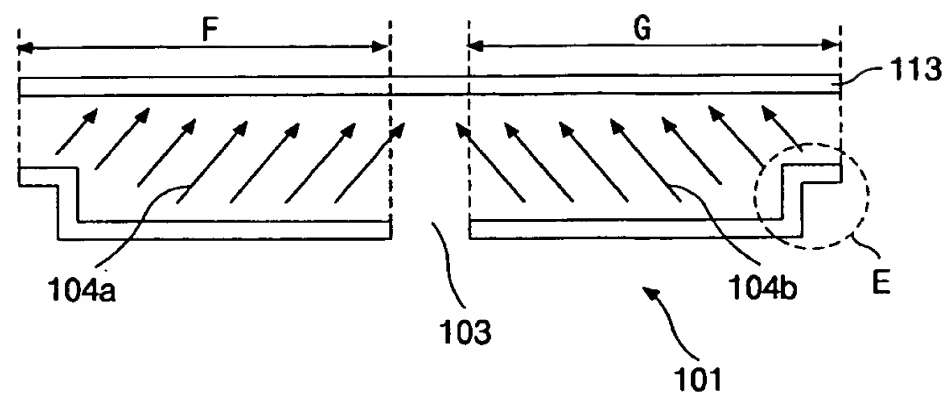
[ FIG. 4 ]



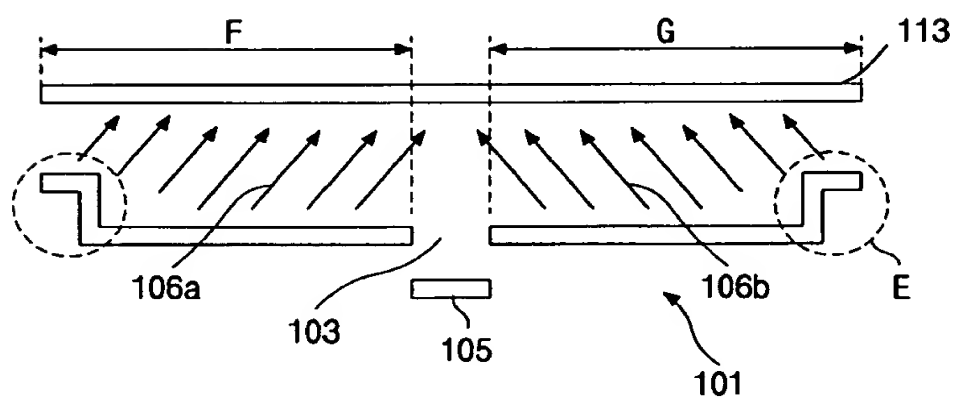
[ FIG. 5 ]



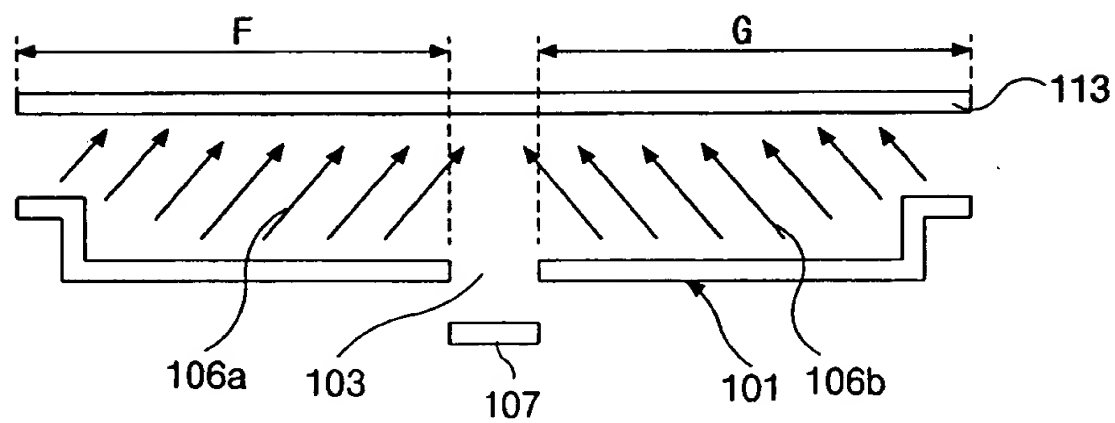
[ FIG. 6 ]



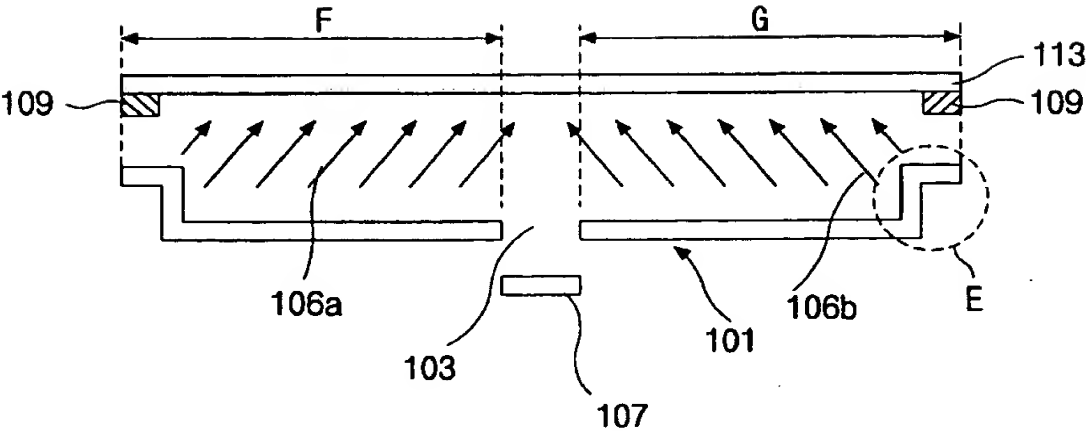
[ FIG. 7 ]



[ FIG. 8 ]



[ FIG. 9 ]



[ FIG. 10 ]

